Adsorptive filter for the removal of arsenic from drinking water

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ABSTRACT: The purpose of this paper is to design a novel module for the removal of arsenic (As) in drinking water. The main removal mechanism of the proposed device consists on adsorption on geomaterial. Adsorptive material is a granular media from Sierras Chicas in Cordoba Province, Argentine. Design of the removal device is based on previous batch and soil column tests performed to evaluate the capability of this material for the removal of As from water. The removal efficiency ranged from 12% to 92% depending on the initial As concentration and flow rate. Obtained results show that the developed filters successfully reduced As concentration in drinking water during more than 100 days.

1 INTRODUCTION

The presence of arsenic in water used for human consumption is a widespread problem in several regions around the world. Cordoba Province at the center of Argentine has aquifers that naturally contain As and are the main source of drinking water for dispersed rural population.
Due to health issues generated by the natural presence of arsenic in aquifers, different remediation techniques have been developed in recent decades for the removal of this compound from water. Available alternatives for arsenic removal include chemical oxidation, precipitation, coagulation, reverse osmosis, adsorption, biological degradation and electrokinetic (Litter et al., 2010). However, adsorption was preferred in many cases due to its low cost and the wide range of reactive materials that may be used for arsenic retention (Mohan and Pittman, 2007; Maji et al., 2008; Jovanović y Rajaković, 2010; Carro Perez and Francisca, 2013a). The adsorbing surfaces or reactive media usually includes activated alumina, iron-based media or other oxides, bauxite, hematite, feldspar, laterite, clay minerals (eg. bentonite and kaolin), activated carbon, cellulosic material, blast furnace slag, surfactant modified zeolite and ion exchange resin, among other.
In this work, a low cost natural material is characterized with the purpose of assessing its sorbent capacity. Available batch and column tests experimental results are used for the development and calibration of a domestic filter for the removal of As in drinking water.

2 EXPERIMENTAL METHODS

2.1 *Materials*

Sorbent material used in this research is a granular media obtained from Cuesta Colorada, La Calera, in Córdoba Province, Argentine. The tested geomaterial is silty sand, classified as SP-SM according to the Unified Soil Classification System (ASTM D2487, ASTM 2007).
Arsenic solutions were prepared from the dissolution of arsenic trioxide (As_2O_3) in an alkaline sodium hydroxide (NaOH) medium. Used arsenic concentrations were 0.1, 0.5, 1, 5, 10 and 15 mg/L to cover the registered As concentration in most aquifers in the center of Argentine. A natural water with As concentration of 0.05 mg/L was also included.

2.2 *As detection method*

Determinations of arsenic in water were performed by means of the Quantifix Arsen10 test kits using the optimized detection method developed by Carro Perez and Francisca (2013b).

2.3 *Filter development*

Two different filters for the removal of As from water were tested in laboratory. A transparent acrylic cell having 5 cm in diameter and 10 cm in length was used to calibrate a 1D mass transport model. These results allow obtaining calibration parameters to simulate the behavior of filters. On the other hand, a commercial 25 liters water container was modified to include a reactive filter for the removal of As. The reactive media was placed between two layers of fine gravel and separated by geotextiles to avoid fines particles migration (Figure 1).

2.4 *Test procedures*

Filters were permeated with distilled water following the constant head technique (ASTM D2434, ASTM 2007) until obtaining constant hydraulic conductivity and then were permeated with arsenic solutions with a known initial concentration. Arsenic concentration in the effluent was periodically measured.

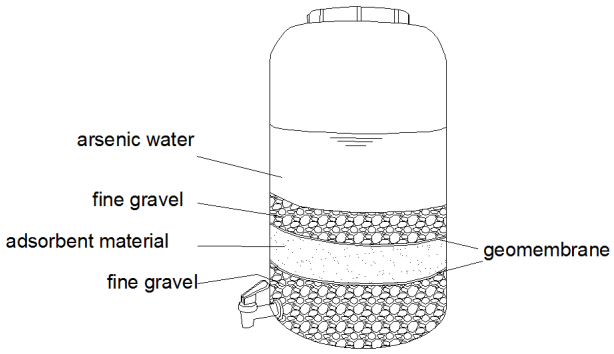

Figure 1. Developed filter.

3 RESULTS AND DISCUSSION

3.1 *Laboratory soil column*

A 1D mass transport model was fitted to experimental results by means of least square fitting of the advection-dispersion-retardation equation. Once calibrated, this model was used to obtain life-time charts for different filters with different lengths and initial As concentrations. Figure 2 presents the change in As concentrations with time for two reactive column of 25 cm in diameter and 10 cm and 20 cm in height, Co = 0.3 mg/L, and hydraulic head 0.25 m. This chart was used to determine the time required for the concentration to surpass 0.01 mg/L in the outlet port. This value is the maximum allowed As concentration in drinking water according to the World Health Organization (WHO). Obtained results are presented in Table 1.

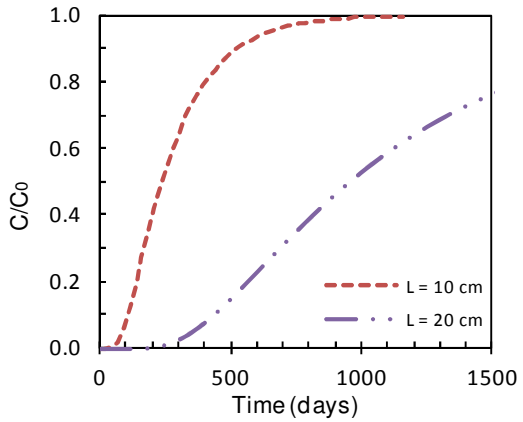

Figure 2. Life time.

3.2 *Case study: Colonia Las Pichanas*

The town of Colonia Las Pichanas is located in San Justo County in the East of Córdoba Province. Rural and dispersed population at this location is near 500 people.

This community is settled in a region with aquifers having high arsenic concentrations according to historical data. In the past decade a 350 meters deep groundwater well was installed for water provision. As concentration in this aquifers is in the 0.04-0.05 mg/L range which is in good agreement with past local regulations. All other chemical parameters make this source of water compatible to be used as a drinking water without any further treatment. However, at the present international regulations recommends As concentrations lower than 0.01 mg/L for drinking water. Then, the use of any filter as the one developed in this work may be necessary at any time. From the As concentration in this aquifer and according to Table 1, the lifetime of filters developed in this work will be close to 100 days.

Table 1. Filter lifetime for a 25 cm in diameter and 10 cm in length filters.

Initial Concentration	Lifetime
mg/L	days
0.05	107
0.1	104
0.3	80
0.5	60

4 CONCLUSIONS

A low-cost module for the removal of arsenic in drinking water was developed. Proposed filter can be used to provide practical solutions to rural and dispersed population without any other source of water. Developed filters were efficient in removing As from drinking water during more than 100 days.

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